RESEARCH AND TECHNOLOGY FOR THE FUTURE

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My predecessors have given you a good view of the space program - accomplishments and what the future may bring. Klein has discussed the role of nuclear energy in space propulsion and electric power generation. Von Braun has discussed large launch vehicles and missions. Naugle has shown the exciting things coming or possible in space sciences, lunar exploration, and space applications.

Dr Welsh has touched on need for broad research program — General in nature

Enabling Technology

The difference between success and failure of these missions, between reaching and falling short of our objectives, between winning and losing a race with others, lies in our knowledge of the flight sciences and our skill for applying this knowledge to the development and operation of space vehicles. We acquire this knowledge and technology through research where new ideas and processes are conceived, are nurtured by theory and experiment, and are brought to maturity in the form of new equipment or operations. A natural characteristic of technology is its multiapplicability; an improvement in guidance or communication equipment, for example, may find many uses in space missions as well as non-aerospace applications. A key to making this process productive, as measured by the creation of new knowledge and techniques, is a continuing research program, well planned and well supported, that has a good balance between the effort in the scientific and engineering disciplines and in the technologies needed to explore the unknown.

Cannot stop-start

The part of the NASA program that I will discuss is concerned with acquiring new space flight capability through research and technology. The primary goal is to provide a sound technology base for performing new and more useful space missions not possible with today's state-of-the-art. This gives the Nation flexibility in choosing the space systems that are the most suitable and economical for accomplishing these missions. A secondary goal is to assist others in solving development and operating problems of existing systems. In striving for these goals, we are advancing national engineering capability and promoting the wide-spread use of new technology.

opening new options

Space program has been open-ended; should maintain minimum 30

In FY 69, the R&D program for research and technology in aeronautics and space is 285 million dollars. Of this, about one third is aeronautics and two thirds space technology. About a third of the research is done in-house, a tenth by universities, and the balance by industry.

Our effort ranges from fundamental to applied research and on to building and testing of prototype equipment for proof of new concepts or the study of complex systems. It is organized into disciplines and subsystems that are used across the board in all space vehicles - structures, propulsion, space power, electronics, for example. However, in describing this work, I will relate it to equipment for accomplishing some of the missions you have heard described.

I will start first with launch vehicles. At present, we have a stable of seven reliable launch vehicles ranging from the all-solid propellant Scout which carries 300 pounds into orbit for a little over a million dollars to the mighty Saturn V which will carry roughly a thousand times more payload than the Scout at a cost that can approach about 200 million dollars. These vehicles drew on the fifty billion dollar missile R&D of the 1950's plus other technology, notably the hydrogen-oxygen rocket technology of the Lewis Research Center, developed during the same period. The launch vehicles, Von Braun

proud

backed by competent teams from government and industry laboratories, have reached or are nearing a stage of perfection and high reliability; they are examples of a national capability of which we can all be very proud. But we who are engaged in research and technology are never satisfied with what is within our grasp - we constantly strive to go beyond this, to improve existing equipment, or to seek entirely new concepts.

Less cost, rely

In the launch vehicle area we are pushed by an urgent problem of another nature - the mounting cost of boosters. The great need for the next generation of boosters is not only to retain the best of the present qualities, such as high reliability, but also to find the means for making booster less expensive to build and operate. This means, for example, simpler launching methods, more economical propulsive energy, recovery and reuse of the more expensive vehicle subsystems, and simpler ground control, tracking and communication. Most importantly, it means that the present costly test and qualification methods must be made significantly more economical. While we can identify these problems, we need to do a good deal more work before we can come up with solutions. One point that comes up almost immediately in speaking of costly boosters is that they are single-use equipment and this leads naturally to the question: reusable why not develop reusable boosters? Unfortunately, the answer is not as simple as the question. We and others have studied expendable versus reusable boosters and find that the technology for reusable boosters is not at hand and that our best estimates of their development and manufacturing costs are very high. This means that their use must be frequent enough to amortize the huge investment required. But this large amount of traffic is not in the forecasts for the next decade and so we are turning to intermediate steps such as a low-cost booster and boosters where the more costly equipment can be placed in the upper stages and recovered.

We are, therefore, focusing a good deal of attention on the concept low-cost single-use boosters and the prime candidate for achieving low cost is the large solid motor. & big dumb liquids We and the Air Force have made considerable progress in the technology of large solid motors. Figure 1 shows the Large Solid Motor test record through last year. You can see that there is a considerable amount of experience with large motors - nine tests of 156 inch diameter motors and three tests of the 260 inch diameter motors. Figure 2 shows the static test of the 260 inch SL3 solid motor in June 1967. Peak thrust was 5.9 million pounds, a world record of high thrust for a single motor, we believe. Near the end of the firing, however, there was a spectacular display resulting from ejection of burning fragments. This was caused by the improper bonding of batches of propellants during loading and is one of the problems that must be cleared up.

easing
[illegible] of

Another problem is lower cost nozzles, insulation, and cases through the use of different materials and techniques. Another problem requiring more attention for achieving lower cost is thrust vector control. We feel that these problems can be solved with one or two more years of technology effort and the firing of another 260 inch solid. Concurrent with this, we are making vehicle design studies and possible missions and these indicate that a vehicle with a earth-orbit payload of about 100,000 pounds is an optimum size for a new booster. This size could be met by using a first stage consisting of either a cluster of 156 inch solids motors or a single 260 inch motor and a modified SIVB as the initial upper stage. We are examining ways that the SIVB could be simplified for this mission as, for example, removal of restart capability. Another way to achieve low booster cost is to have a simpler liquid stage, the so-called "big dumb booster." Comparison of cost

TVC

100K
in orbit

estimates for the large solid and liquid booster do not show significant differences and indicate that more research is needed. At the moment, however, the large solid has the edge in terms of technology readiness.

Nerva

In addition to pushing the technology of chemical boosters to reduce cost, we are also pushing forward to develop the NERVA 75,000 pound thrust engine to increase our booster capability. Klein has amply covered this important aspect of our work, which is carried out jointly with the Atomic Energy Commission, but let me add this observation. A great amount of study, debate and soul searching, both within and outside the agency, has emanated over the issue of development of the NERVA engine. The technology program has been an outstanding success with reactor and breadboard engine systems operating smoothly over a wide range of conditions. Figure 3 is a view of an operation typical of the 509 minutes of accumulated reactor and engine system test time from 1964 to now. The technology is at hand - hard won technology that assures us the opportunity for continued leadership in this field. We believe the Nation should take full advantage of this technology by proceeding with the development of a flight engine. The first logical use of the engine would be for a stage ~~to replace~~ the SIVB of Saturn V.

Success

509 min. test time

Fig 3

We are recommending that the NERVA engine and stage be ready as early as 1977 for a possible mission. We are working with other NASA offices in studying planetary and other types of missions that can best take advantage of the unique capability of the NERVA engine.

Space Stations + lunar explor.

The two obvious manned flight activities beyond Apollo are earth orbiting laboratories and lunar exploration. I have spoken about the booster for lifting payloads to orbit and beyond; now I want to talk about man's return from earth orbit or lunar exploration. All of us have witnessed the successful parachute sea landings of Mercury, Gemini, and the first Apollo landing October 22. You must be impressed also with the extensive use of recovery forces that these landings involve.

Land landing

Clearly a simpler recovery method than parachute landing in the sea is necessary for reduced cost of round trips to earth orbit or to the moon. Research has been under way for some time on the concept of steerable parachutes for land landings. Figure 4 shows one type of steerable parachute called the parawing. Over a thousand manned landing tests have been made with a parawing having a keel or centerline length of about 20 feet. The next objective is to investigate materials, fabrication techniques, Parawing

packaging, deployment, aerodynamics, and structural characteristics of a parawing with a keel of about 100 feet and capable of landing a 15,000 pound spacecraft.

Lifting Body

The second recovery method for manned return is the lifting entry concept. Lifting entry vehicles have sufficient lift so that they can glide and maneuver in the atmosphere and land horizontally in the same manner as aircraft. Such vehicles may carry a small propulsion unit for maneuvering for landing. The concept also offers a possible way of recovering the expensive subsystems of a booster such as guidance, controls, power, and rendezvous propulsion. While conceptual configurations have been developed for a range of hypersonic L/D's, one class - the lifting body - is further advanced and is presently undergoing investigation to determine the handling characteristics from supersonic speeds down to landing. Three configurations are in the test program. These are the HL-10, M-2, and X-24A. The M-2 is inactive following an accident on landing. Flight tests are under way on the HL-10, shown by Figure 5, and are highly successful. The X-24A shown by Figure 6 is being readied for tests. Heat shield technology, including research on ablative materials and the effect of ablative gases on heat transfer, constitute ancillary investigations.

Types

Fig 5

Fig 6

Flight testing

Sometime in the future, a lifting body equipped with ablative surfaces may be tested for the entire flight regime from orbit to landing. Even further in the future are completely recoverable vehicles, possible using an air breathing propulsion system for the initial stage. This would be the merging of space transportation needs with hypersonic aircraft. We submit that research towards lower cost space transportation systems is one of the greatest research incentives in the space program.

Let us now turn to spacecraft and their trends, starting with orbital types.

large Space Structures

Radio astronomers see, as an ultimate need, an antenna of 20 kilometers diameter for observations between a few hundred MHz and a few hundred KHz. This obviously will require major advances in structures technology. We are working on one concept for a 1.5 Km diameter structure. It uses thin aluminized ribbons arranged in a large open grid with spacing between ribbons of about two feet. The ribbons appear preferable to fine wires to minimize degradation from meteoroid impacts over a long time. The parabolic form is provided by the design of the grid and the supporting structure of wires from the central mast. The shape is maintained by a slow rotation of the antenna about its axis of one revolution ever 16 minutes. Figure 7 illustrates a deployment technique for such an

Fig 7

antenna. Initially, as packaged for launching, the entire system would be in a cylinder 18 feet in diameter and 20 feet long. The five sketches on the left of the figure illustrate sequences in the deployment. It begins at the extreme left with an extension of two auxiliary masts from the initial package on which are mounted small jets. These jets impart an initial spin. As spinning begins, the antenna grid and its restraining lines are unreeled from storage rollers and bobbins by centrifugal force. The initially flat mesh disk becomes gradually larger in diameter as indicated in the next two sketches, and as it does so the rate of rotation decreases. As the antenna net achieves full diameter, as indicated in the fourth sketch, the central mast starts to extend. The fully deployed system with the antenna net achieving its design parabolic form is shown in the fifth sketch at the extreme right. We have conducted preliminary deployment experiments on two and five meter models in a vacuum chamber. This type of experiment is limited by gravitation and eventually we will have to go to a zero gravity environment.

Pointing

Another important aspect is that relating to pointing the antenna. It will be necessary both to sweep the antenna through all directions for scanning and to point its axis precisely toward a signal source.

A promising control technique would utilize the interaction of electrical currents in the rim of the antenna with the Earth's magnetic field. Consequently, we are concerned with the effects of the Earth's magnetic field on the antenna in order to determine if the magnetic field forces can provide the required pointing torques without excessive distortion of the antenna surface. Some preliminary tests with a small model have been conducted to study the effects of a magnetic field on this type of flimsy network structure. A picture of this dynamic model under magnetic field test is shown at the right of the figure.

I have given only the highlights of this work but it illustrates some of the painstaking research and technology that must precede the development of equipment for the astronomer to use in probing beyond our solar system.

Optical observatories

We are also working on the technology of optical observatories where there are many problems, such as maintaining the accuracy of the mirror, very fine pointing control, and structural stability from thermal gradients and elasticity, but I want to move on to other types of spacecraft.

Space Stations

Large manned orbiting laboratories will need advances in many technologies - control and stabilization, shielding and meteoroid protection, thermal balance, electric power, life support, communications and data handling, automatic rendezvous and docking, ~~and others.~~ I want to touch briefly on only two types of activities - human performance and life support.

To many people, the limiting variable, the greatest unknown is the development of long-duration space flight capability, in man himself. As a former submariner, I am well aware of many of these problems - confinement, stress, etc. - and the amazing adaptability of man but I can also appreciate how these are accentuated in space along with other factors not present in our experiences on earth. We need to know more about normal man and his limitations so that we can be assured we have the best combination of man and machine to carry out space missions. Key to research on man are innovations for measuring his functions and his responses to physiological and psychological stimuli characteristics of long-duration flight.

One innovation is a device developed to measure the physiological effects of flight stress in aviators but is equally applicable to experiments on space flight stresses. It is an elastic vestlike garment (Figure 8) which contains large, segmented, dry silver-coated electrodes. It does not require any skin preparation or paste. The vest holds the dry electrodes against the skin to pick up the electrocardiogram signals. Using several electrodes properly placed, a vectorcardiogram can be obtained which permits the physician to visualize the heart's electrical activity in three dimensions. The vest is easily donned and may be worn for long periods without discomfort.

non invasive blood flow

Another new instrument measures the velocity of blood flow by the use of a noninvasive ultrasonic technique. When placed on the skin directly over a blood vessel it propagates ultrasonic energy, measures the return signal, and uses the doppler principle to determine velocity.

fig

A third bioinstrument innovation determines blood pressure within the veins and arteries ~~of animals~~. It is an intra-arterial instrument ~~catheter~~ with a capacitance type transducer small enough to be threaded through a hypodermic needle. Experiments have shown that signals are recorded more faithfully with this transducer than with other available devices. On the left of Figure 9 the device is shown held by a person threading it into a small tube cannulae in preparation for injection. On the upper right is a magnified view of the device showing internal construction. The recorded pattern on the lower right shows a comparison with results from a commercial transducer. High frequency components of the pressure wave are better recorded with this capacitance transducer.

Sensors

Two sensors spaced a known distance apart can determine the pulse wave propagation velocity which gives a measure of the elasticity or hardening of the arteries. Additional research is planned toward assembly of two transducers arranged in a single ~~cathether~~ instrument, as in a pitot probe, to determine the blood velocity by measuring the total head pressure and the static pressure. Due to their small size, high sensitivity and high frequency response these transducers should find many uses in research and clinical applications. It is interesting to note that the transducers used were a type originally designed to measure pressures of aircraft flight models in wind tunnel tests and illustrates the important cross-feed between different disciplines operating in a common environment.

cross-feed

With improved measurement techniques and an orbiting laboratory, we will be equipped to study man's performance in space and determine his capability for more difficult missions in the future.

Life Support

Life support is a key technology for extending man's capacility in space. Air for breathing, water, food, heat, and moisture must be supplied; carbon dioxide, body waste, heat, odors, gases from equipment, and other harmful substances must be removed. In Mercury, Gemini and Apollo, ~~life support~~ waste is discarded after use. For long duration trips, however, the stores needed become great so a major consideration is resupply and its frequency. Obviously a manned orbiting laboratory and lunar bases can be resupplied without great difficulty so the question of on-board regenerative systems that treat and reuse certain ingredients versus discard of all waste becomes a consideration of safety and economics. For long-duration, self-supporting missions, such as to the planets, regenerative systems become essential. In all cases repair and replacement techniques are necessary for sustained operations. Both regenerative systems and repair-replace techniques are in the early stages of technology and the manned orbiting laboratory is ideal for proof of new concepts in life support equipment.

regenerative Systems

algae

We are working on water and oxygen recovery, solid waste management, sensors for oxygen, carbon dioxide, water vapor, and inert gas, trace contaminants, and food management. Water recovery represents a major weight saving potential and I will discuss it as a typical example of life support research.

One group of studies investigate methods to recycle waste water for drinking and washing purposes. The basis of one such system is the evaporation of clean water from urine-saturated wicks. Hot air evaporates clean water from the wick leaving a residue behind. Approximately 4% of the urine processed was retained in the wicks in the form of solids; the rest evaporated and was reclaimed as clean water. However, this method has several major problems particularly short wick life. Improved wicks have been made by they ~~remain the limiting~~ factor of the method.

Chlorine

We have found it desirable to chlorinate stored water but the use of chlorine presents special problems in a closed environment because of its toxicity. This has been overcome by generation of chlorine only as needed by a technique using the electrolysis of a chloride solution. Electric current controls the rate of chlorine generation and makes automation of the system an easy step.

A promising method of water reclamation is a vapor diffusion technique which appears simple, compact and highly efficient. A laboratory model has been built that uses a semipermeable membrane in an evaporator and a porous plate sublimator to condense the water vapor and separate condensate from diffusion gas. Tests with this laboratory model look very promising. For example, it is estimated that only 15 pounds of water at launch will be required for each man for 100 days using such a system as contrasted to 600 pounds of water per man needed ~~on~~ in the same period without reclamation.

A reverse osmosis technique appears to be a promising method for wash water reclamation. The technique, however, requires a special membrane which NASA has not yet developed. Last year, the Office of Saline Water, which was conducting related work, did some test for NASA on the use of tiny hollow glass tubes for membranes and this joint effort is continuing.

Similarly, representatives of the Federal Water Pollution Control Administration have met with NASA scientists to exchange research information on the handling of wastes to prevent water pollution. As a result of meetings last year, NASA and FWPCA undertook a joint program on a new process which removes dissolved organic compounds from water by oxidation. A specially prepared catalyst is required. It is expected that the process can be used by NASA to reclaim water from urine or by the FWPCA to remove stubborn, dissolved organic compounds from municipal sewage and industrial wastes.

& large space station

Lunar exploration is ~~a~~ logical follow-on to the first Apollo landing. Nuclear electric power systems, based on SNAP 8 technology, are particularly applicable here. Smaller and mobile power equipment will also be needed. In speaking of space power in general, the multiplicity of power ranges and combination of energy sources and conversion methods, coupled with the universal need for electric power in space and on earth, indicates that the potential pay-off from research in space power systems is high. Greater emphasis on a few highly promising systems is indicated for reasonable progress. Klein has described a major portion of this program, the part involving nuclear energy. Non-nuclear research includes batteries, fuel cells, and solar cells.

Batteries

Research on a new rechargeable battery with one or two auxiliary electrodes has progressed to the point that it has been selected for use on the Orbiting Astronomical Observatory (OAO) spacecraft and on the Apollo Telescope Mount ~~planned for launch in 1970.~~ These are two important uses of battery technology developed under this program. Heating during recharge and effective battery weight are reduced with a significant increase in cycle life (number of reliable recharges).

Silver zinc rechargeable battery

We are now trying to extend the cycle life of these batteries to five years. As a result of improvements in the manufacture of zinc electrodes, incorporation of the new separator and better packaging of components, five amp-hour, silver-zinc batteries have recently been cycled for well over 2,500 cycles at 20% depth of discharge, and over 2,000 cycles at 30% depth, both at room temperature and for simulated 90-minute orbits. Even at 212°F, more than 500 cycles were run. We thus have, for the first time, a truly rechargeable silver-zinc cell. This is now being scaled up to larger size and modified to permit sterilization in sealed condition.

Solar cells

Fig 10

In solar cell technology, we are striving towards the goal of 20 watts per pound and total power levels up to 50 kilowatts. This requires very light structures to hold the cells and one approach to this is bonded beryllium as illustrated by Figure 10. The 13 ft. 8 inch spar which weighs about two pounds is the longest continuous beryllium structure ever assembled. As a result of this work, it is now possible to roll sheets of beryllium longer than

13 feet and to fabricate complex adhesively bonded structural joints such as illustrated in the figure. The assembly on the left of Figure 10 would require 40 spars and eight joints of the type illustrated.

Fig 11

rollup

Another approach to large solar power is a retractable solar array such as illustrated by Figure 11. This shows the potential of the "rollup" or window shade concept to achieve moderate weights (for example, 12 watts per pound), the most compact stowage for launch, and the capability to be automatically deployed and rolled up again many times. We are trying to increase the power level from 500 watts to 2,500 watts, requiring 250 ft^2, and to increase performance from 12 to 30 watts per pound. The higher power level and reduced weight are needed for potential future missions using solar electric propulsion, for broadcast satellites, and manned space flight.

planetary spacecraft

Let us now move on to planetary spacecraft. Planetary missions involve a wide variety of spacecraft including interplanetary probes, solar probes, planetary orbiters, and planetary and planet satellite landers, ~~and, eventually, manned planetary landers~~. These have in common the need for efficient propulsion systems, attitude control, accurate guidance and navigation, ample electric power, versatile sensors, high data storage capacity, and high communication rates over long distances, all of which must be designed to withstand the hostile elements of the space environment. Additional requirements are high temperature systems for solar probes and Venus landers, atmospheric entry vehicles, decelerators, and landers. I will touch on two of these subjects, atmospheric entry and landing and electronics.

entry into planetary atmos-

The atmospheric entry successes of Mercury and Gemini, based on earlier technology, tend to lessen awareness of the much larger problems of entry that must be solved for successful entry of probes into planetary atmospheres and, eventually, earth atmosphere entry from planetary missions at higher speeds. These problems stem from lack of knowledge of fluid flow processes at very high velocities and unknown composition of planetary atmospheres. Present effort, focused on obtaining a better understanding of turbulent heating and on ablation in the presence of a turbulent boundary layer, at very high velocities, ~~is limited~~ by our ability to simulate flow conditions and heating ~~rates.~~ For

Soviet

example, our estimates show that the Russian Venus probe experienced radiative heating rates of about 6 kilowatts ~~per~~ square centimeter. These levels considerably exceed, our present test capabilities to study the heating environment or the response of an ablation material to that environment. If a probe of the Jovian atmosphere should be desired, technology permitting entry into hydrogen-helium atmospheres at speeds of about 50 kilometers per second would be required. Again, these conditions exceed our current experience and our ability to conduct ground-based experiments and clearly calls for innovations both in the research technique and in gaining the needed technology.

Jovian

Present research indicates, however, that blunt conical shaped entry vehicle would be suitable for Mars entry. Once decelerated we encounter the problem of deceleration from supersonic speeds to landing.

Last year we successfully completed the first phase of high-altitude flight tests of large parachutes for this purpose. These tests provided us with data on opening shock loads and deployment at supersonic speeds (M 1.6), and low atmospheric densities in the large wake of the bluff entry vehicle. We also obtained data on the deceleration and orientation characteristics of the parachute. The extent of the technology acquired is indicated in Figure 12. The artist's sketch on the right of the figure illustrates the nature of the problem. Here we show the initial stages of deployment of a large parachute extracting the payload from a Mars entry

Fig 12

aeroshell. One of the problems investigated was that of opening and deployment of the parachute at supersonic Mach numbers and low atmospheric densities in the wake of the large bluff entry vehicle. We also needed to know what the opening shock loads were during this period. Following deployment, the fully opened canopy then decelerates the payload to the desired terminal velocity and provides aerodynamic orientation to allow on-board instrumentation to control the precise firing of retrorockets for the final soft landing. This requires parachutes which are very stable during descent; therefore, these characteristics were also investigated in our flight research program.

On the left of the figure, parachute size (diameter in feet) is plotted against Mach number. Prior experience with parachutes and other decelerators is indicated by the shaded region along the vertical and horizontal axes. At that time we had experience only at very low speeds with large parachutes on the order of 180 feet in diameter. At the other end of the Mach number scale, experience at higher Mach numbers up to about four was with small parachutes and other drag devices of the order of a few feet in diameter. The region of interest for a Mars probe is indicated in the center of the graph. The cross-hatched areas shown within this region represents those covered by current research program. Parachutes up to 85 feet in diameter were tested at Mach numbers up to 1.6, and smaller parachutes up to 40 feet in diameter were tested at Mach numbers near 2.6.

Two parachute configurations in the program were identified as having satisfactory characteristics for use in the Mars probe application. Detailed design data were obtained which have shown that such parachutes can be made to operate properly at considerably higher speeds than was previously believed possible. We plan to continue the investigation of parachutes and other decelerators using the rocket-launch system to obtain additional data.

Planetary spacecraft will also stretch almost every aspect of electronics technology - guidance, control, tracking, data acquistion, storage and handling, and communications. The need for increased reliability and life, important for all missions, is accentuated for missions to the planets and beyond because some might call for useful lives up to ten years.

Fig 13

The packaging of 39,220 individual electronic parts into a 575 pound spacecraft (Mariner IV) mentioned by Naugle underscores this need for high reliability as well as the rising complexity of space vehicles. This rising complexity is illustrated by Figure 13.

Explorer I had about 500 discrete parts. Mariner-Venus 67 had almost two orders of magnitude increase in parts - about 41,000 parts. However, some were incorporated into integrated circuits so the number of devices wired was about 25,000 as shown by the bottom curve. The trend shown by the upper curve of discrete parts count is a rapid rise and underlines the need for integrated circuits or multifunction devices to reduce the electronic complexity. We are quite excited about a revolutionary new trend in electronics with the somewhat confusing misnomer of <u>large-scale integration</u> or LSI. Life and reliability of electronic parts increased by orders of magnitude as technology progressed from vacuum tubes to transistors to integrated circuits. The latter have a number of parts, such as transistors, resistors, etc., formed and connected on a single chip of silicon to perform a complete function. The success of single-function integrated circuits has pointed out the feasibility and promise of circuit integration on a larger scale. The new field-effect transistors, ~~the so-called MOSFETS,~~ have enabled us to make larger circuit arrays, more simply and economically, while performing many electronic functions. Figure 14 compares the single circuit device that performs one function with a large scale integration (LSI) array that performs 100 functions. The LSI device has one-third the

order of mag increase

LSI

Fig 14

number of process steps, 1/100 the hand connections, and at least one-tenth the weight and volume. Already a few LSI devices have been flown on IMP satellites by the Goddard Space Flight Center and have performed well. It is this type of emerging new technology that underscores both the need and the potential of increased research in electronics. We are increasing our efforts in electronics research through the Electronics Research Center in Cambridge, Massachusetts. Hi reliability & as consequence lower cost

nuclear

A/C

~~Before closing I want to mention the possibilities of nuclear aircraft. You recall the abortive effort some years ago for this application. Since that time, aircraft have grown considerably larger. The jumbo jet, subsonic, for example, will weigh about 700,000 pounds and a million pound aircraft may not be far away are on the design board. These trends to very large sizes have led us to take a fresh look at the use of nuclear propulsion for aircraft. Our work thus far consists of design analyses and a study of the safety problems involved.~~

In closing, I have described some research trends and problems in space technology. We believe this program, along with the other programs described here, provide a unique and peaceful means for this Nation to develop new capability in science and technology that will benefit us all.

need for adv research on broadfront

stimulus to additional research

Edwelch need to sell to public

LIST OF FIGURES

LARGE SOLID MOTOR TEST RECORD

MOTOR DESIGNATION	TEST DATE	PROP WGT (10^6 LB)	MAX THRUST (10^6 LB)	BURN TIME (SEC)	TVC TEST	COMPANY
156—1	5—64	0.42	0.9	108	JET TABS	LOCKHEED
156—2	9—64	0.63	1.1	143	JET TABS	LOCKHEED
156—3	12—64	0.69	1.4	126	GIMBAL	THIOKOL
156—4	2—65	0.80	3.3	59	NONE	THIOKOL
156—5	12—65	0.69	3.1	55	LIQUID INJ	LOCKHEED
156—6	1—66	0.27	1.0	65	LIQUID INJ	LOCKHEED
156—HG	4—66	0.16	0.3	122	HOT GAS INJ	LOCKHEED
156—7	5—66	0.13	0.4	110	LIQUID INJ	THIOKOL
156—9	5—67	.27	1.0	77	FLEX BEARING	THIOKOL
260, SL—1	9—65	1.7	3.6	114	NONE	AEROJET
260, SL—2	2—66	1.7	3.6	114	NONE	AEROJET
260, SL—3	6—67	1.7	5.9	70	NOZZLE STRUCTURE ONLY	AEROJET

DAC DATA

NASA HQ RP67-17073
Rev. 1-25-68

Figure 1

STATIC TEST OF SL-3 SOLID MOTOR

JUNE 17, 1967

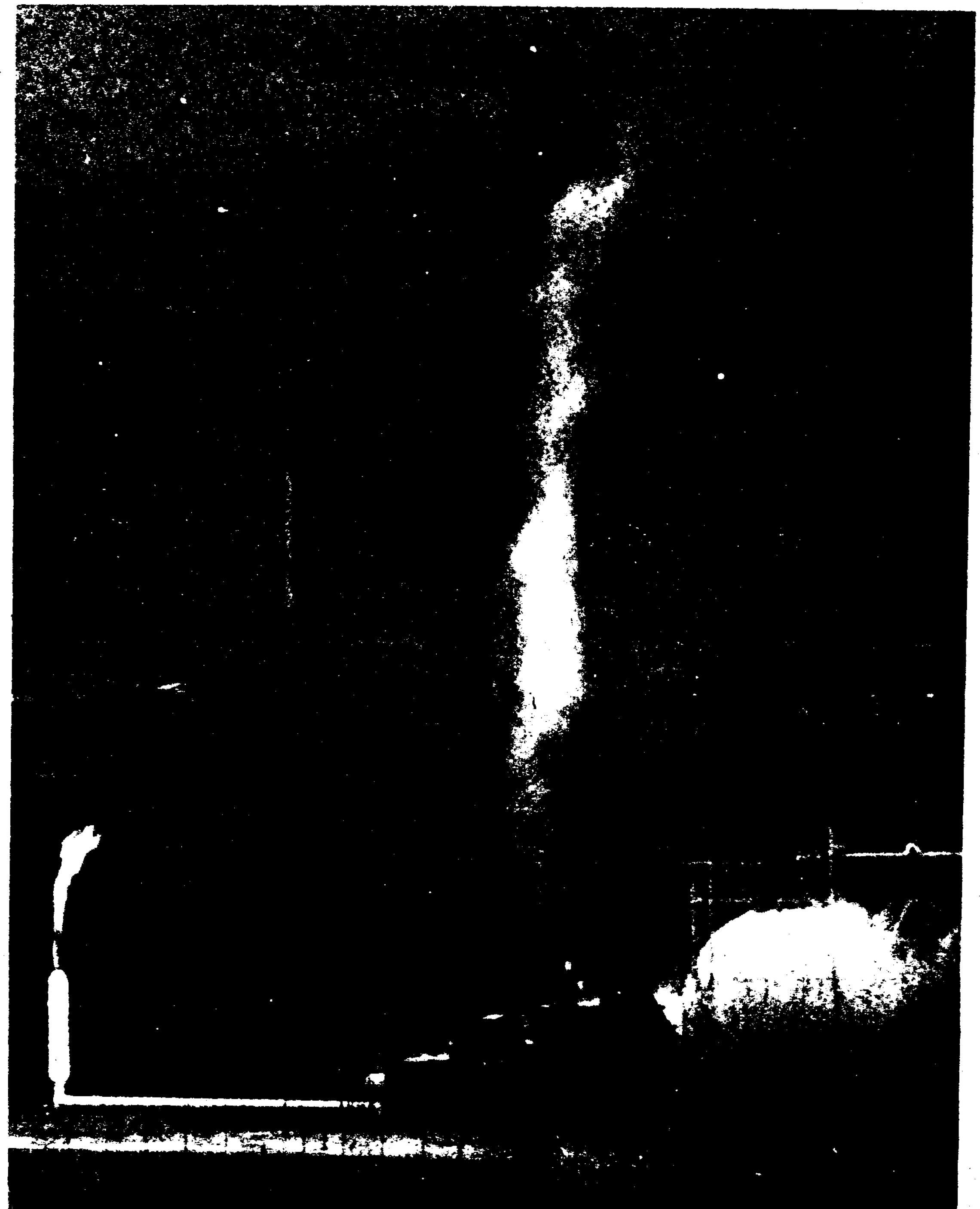
PEAK THRUST — 5.9M POUNDS

THROAT DIAMETER – 89 INCHES

WEIGHT ——— 1.7M POUNDS

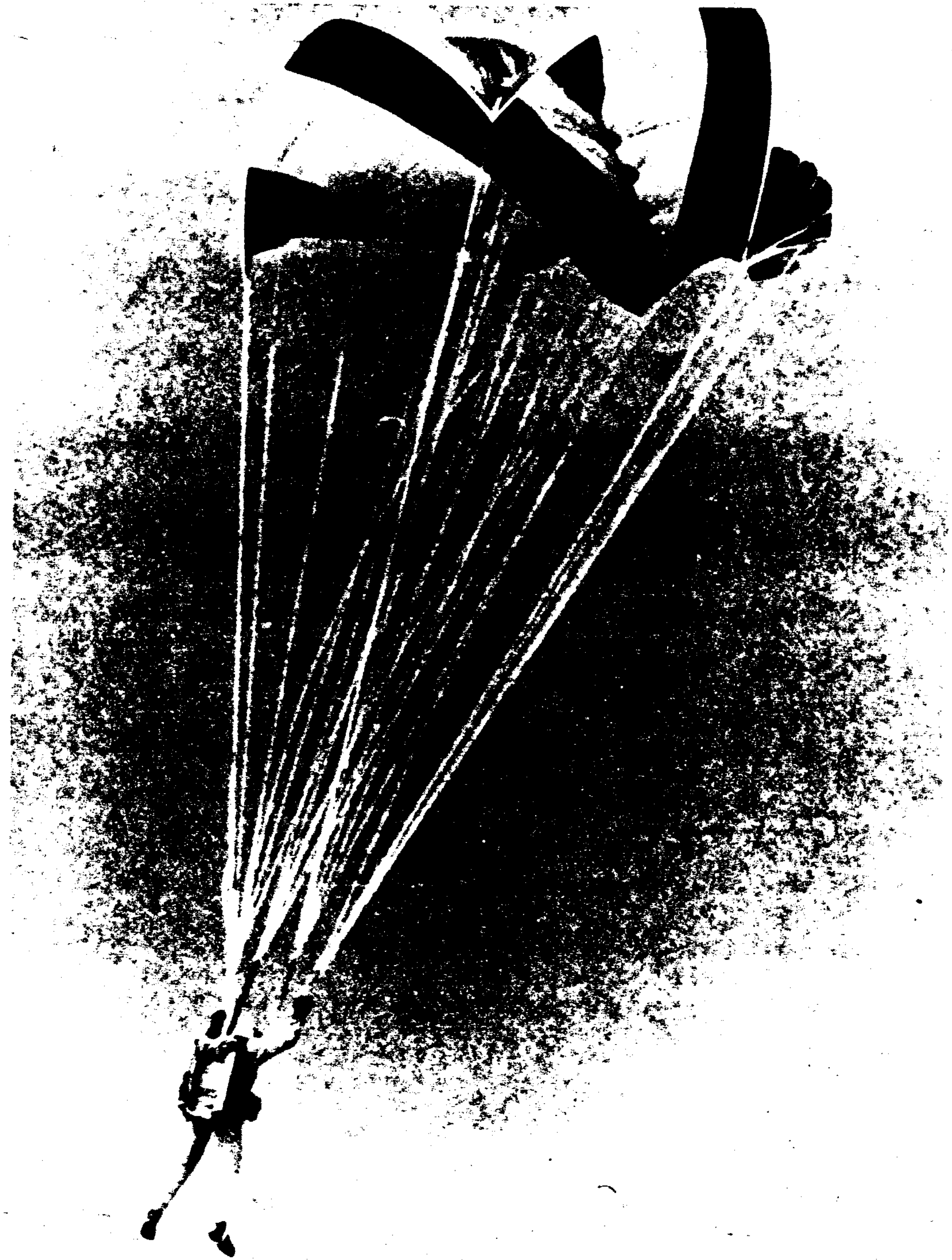
NASA HQ RP67-17040
Rev. 1-25-68

Figure 2



NASA HQ RC68-15628 1-8-68

Figure [illegible]



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1-18-68

Figure 4

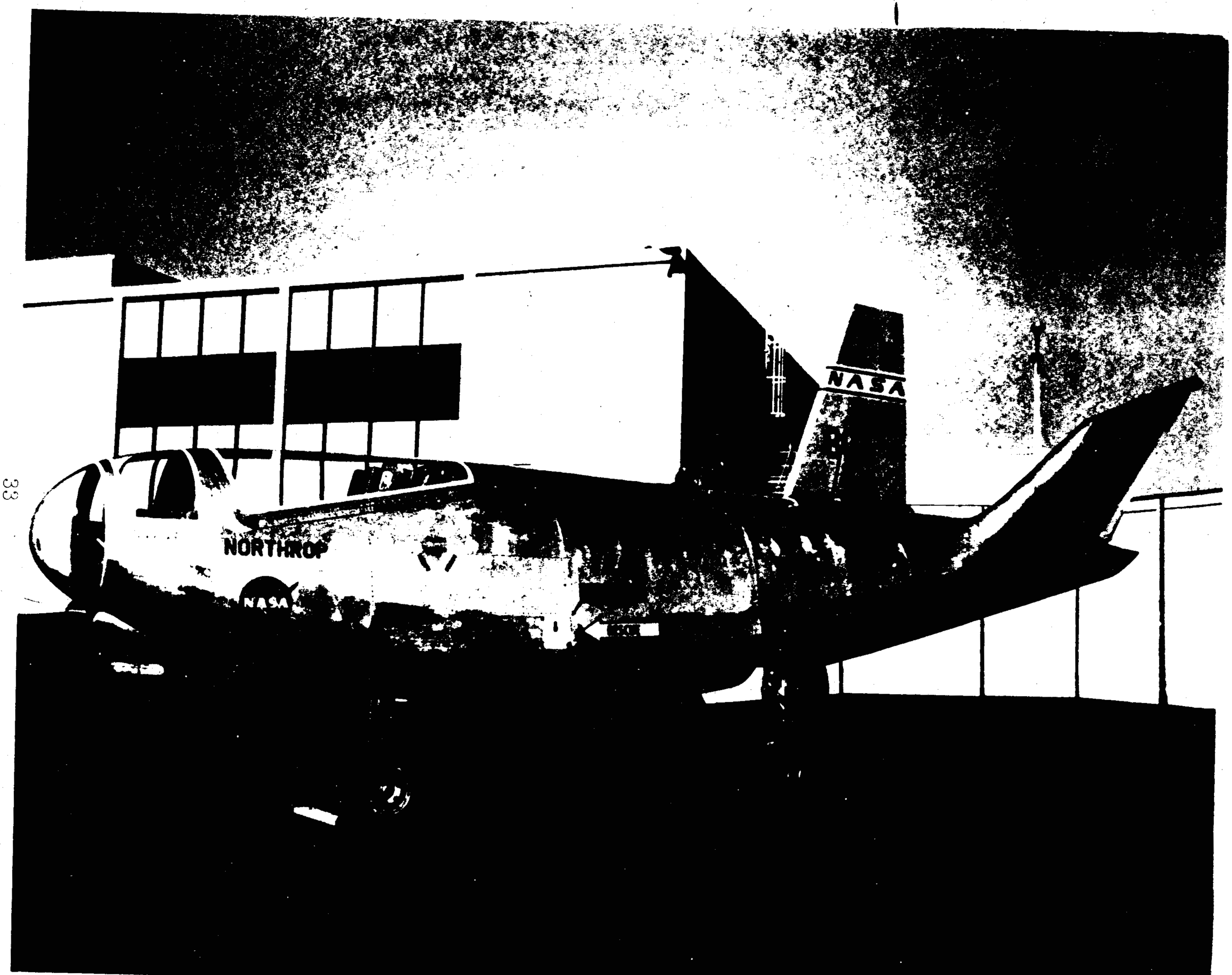


Figure 5

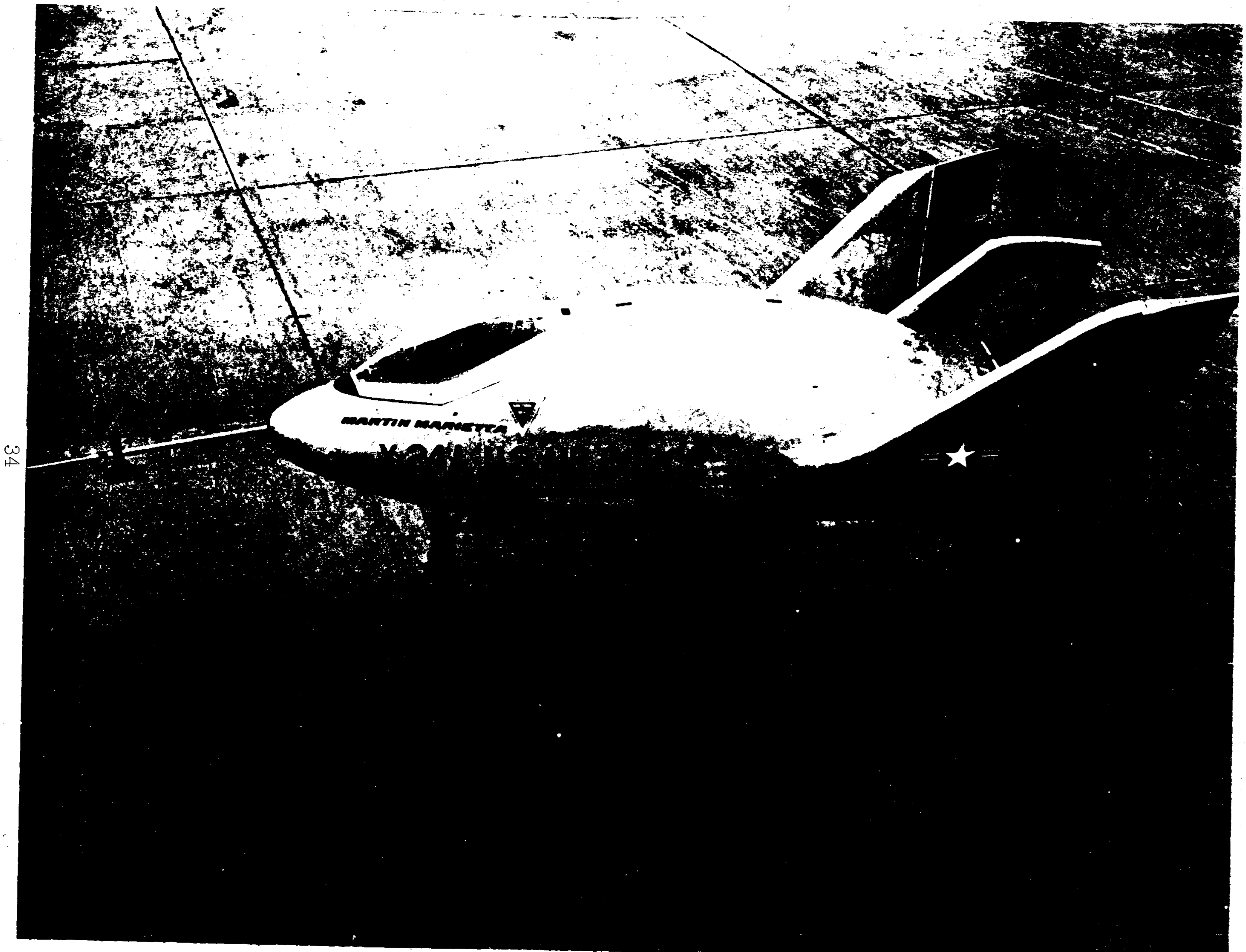
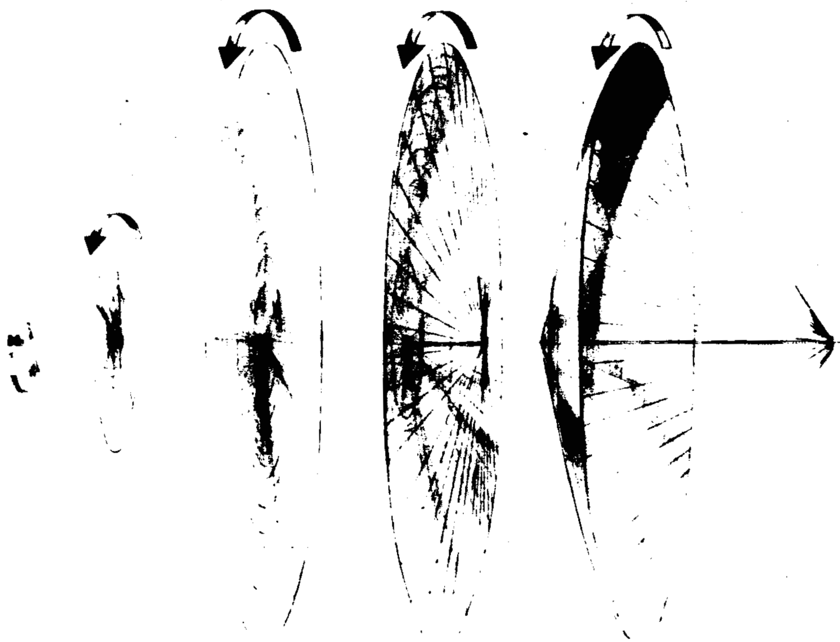
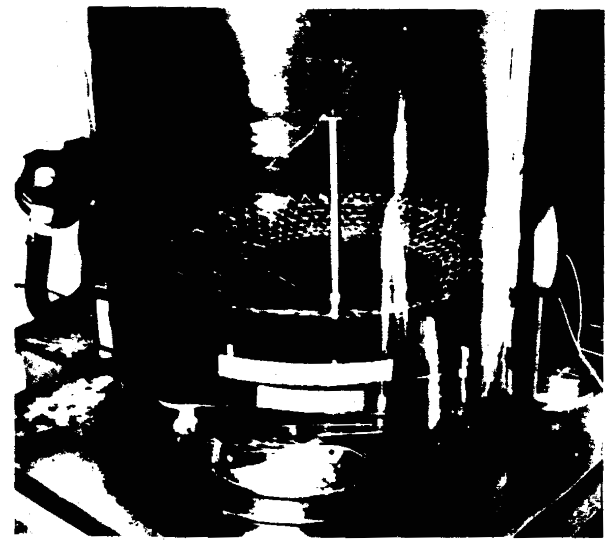


Figure 8

STRUCTURES TECHNOLOGY - ORBITING RADIO TELESCOPE



DEPLOYMENT SEQUENCE



MAGNETIC FIELD TESTS WITH DYNAMIC MODEL

EFFECTS OF EARTH MAGNETIC FIELD

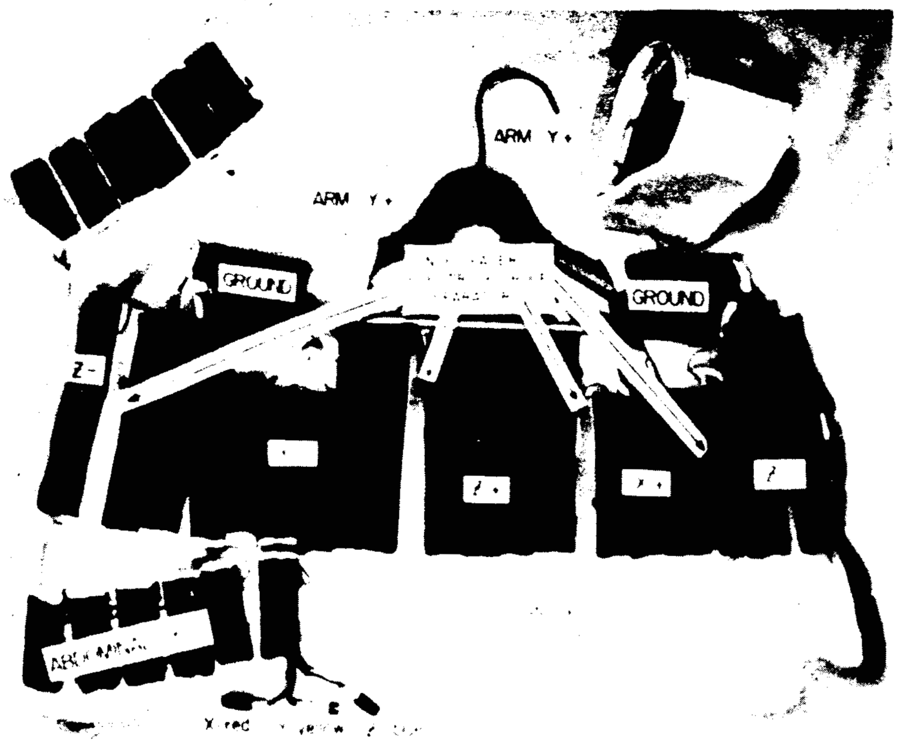
- PROVIDE REQUIRED POINTING TORQUES
- DISTORT ANTENNA SURFACES

NASA RV68-1126
1-12-68

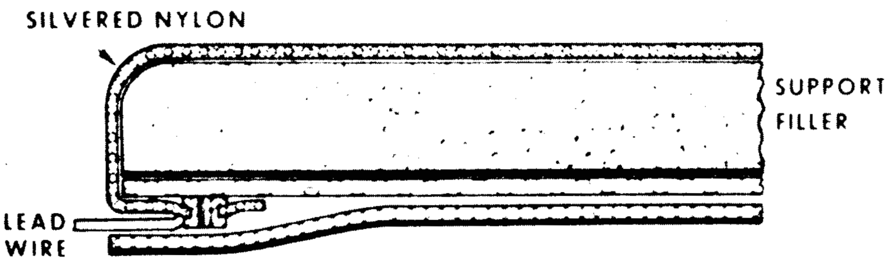
Figure 7

BIOINSTRUMENTATION

STRESS EFFECTS IN AVIATORS



DRY ELECTRODE PADS IN VEST



CROSS SECTION

FLIGHT RESEARCH CENTER

Figure 8

INTRA-ARTERIAL PRESSURE MEASURING SYSTEM

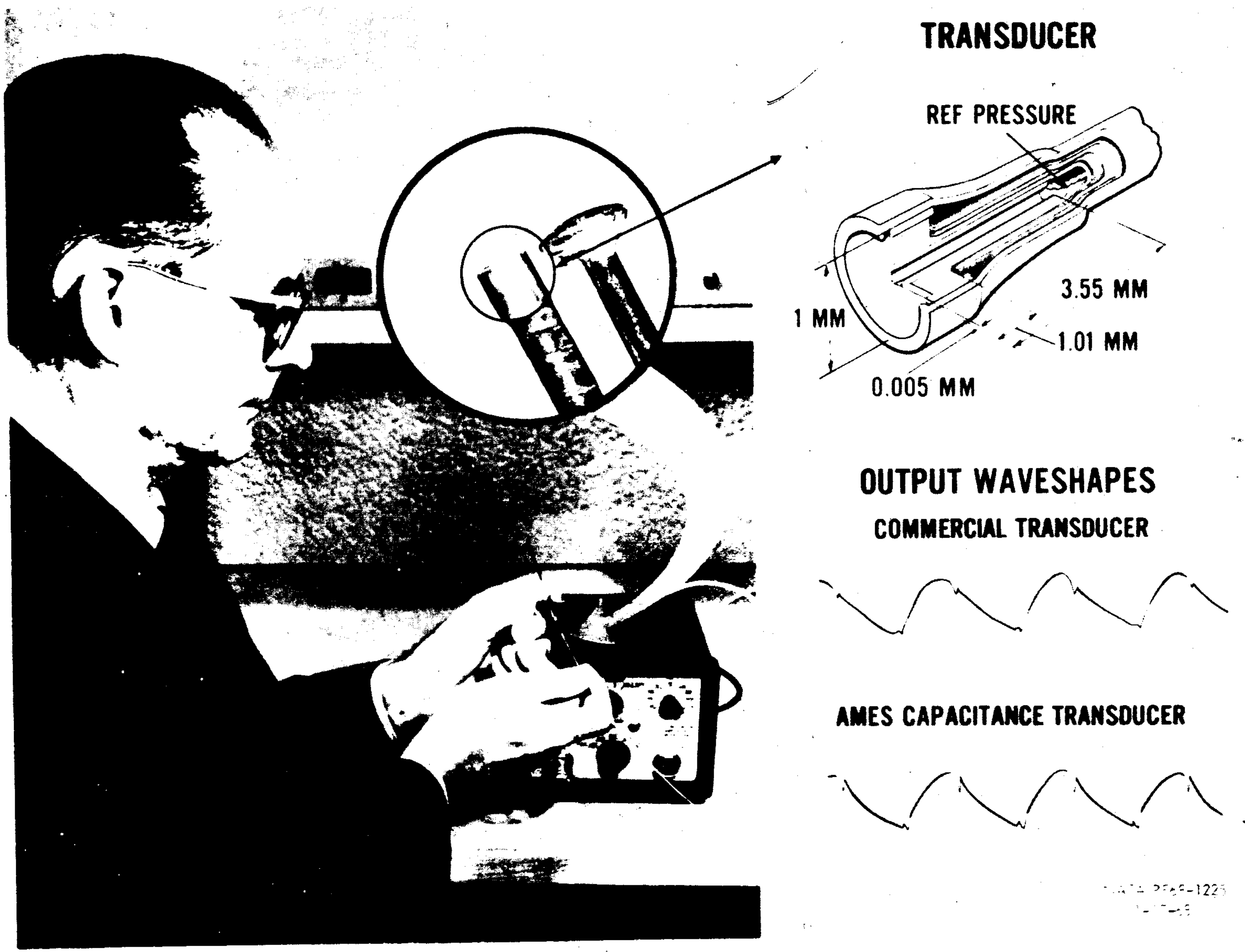
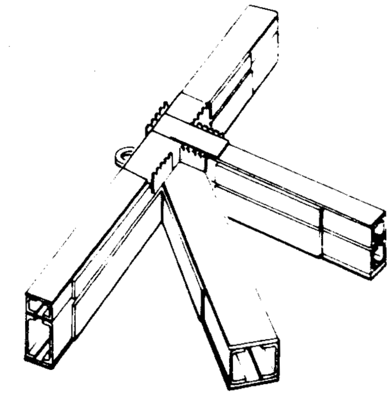


Figure 9

HIGH POWER SOLAR CELL ARRAY

PROGRESS IN LIGHTWEIGHT BONDED BERYLLIUM

GOALS: 5000 FT^2, 50KW, 2500 LBS



COMPLEX JOINT; ARRAY SUPPORT STRUCTURE

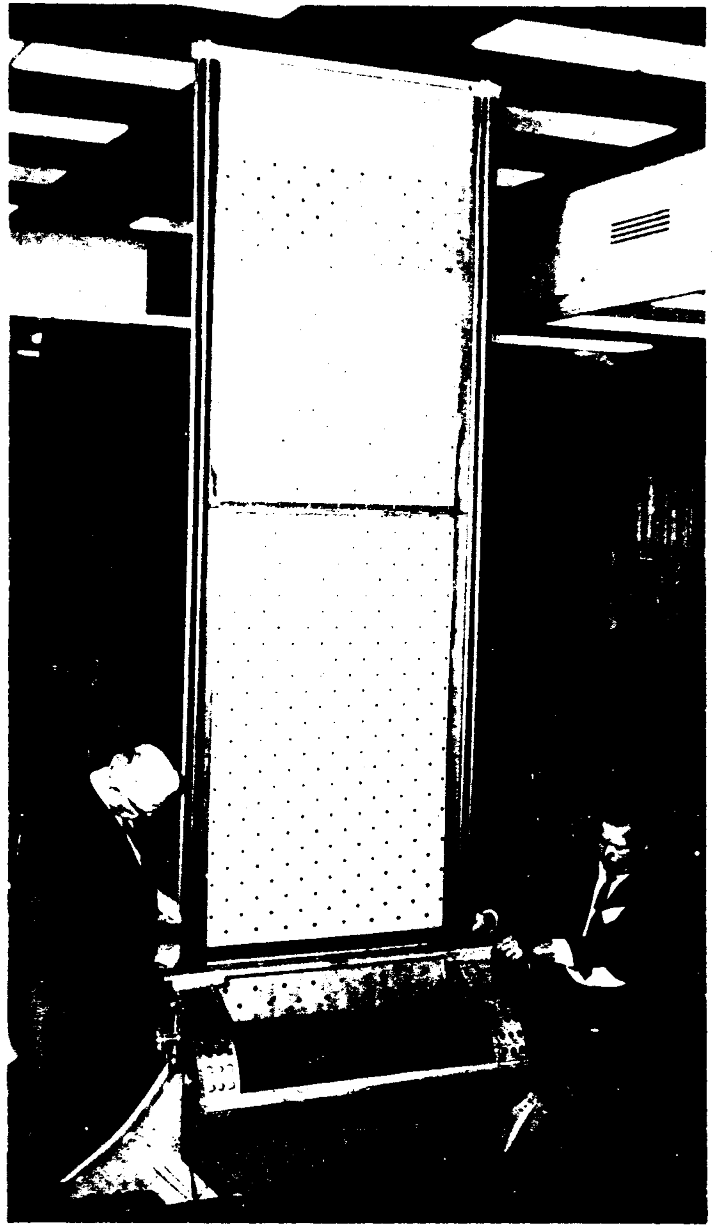
13 FT-8 IN, 2 LB, SUBPANEL SPAR

Figure 10

RETRACTABLE SOLAR ARRAY

1967
RESULTS

- DEMONSTRATION OF 50 FT^2 MODEL
- ACHIEVED 12 WATTS PER LB. IN 500 WATT SIZE
- INITIATED WORK TOWARD ADVANCED DESIGN



50 FT^2 MODEL
NASA RN68-1137
1-12-68

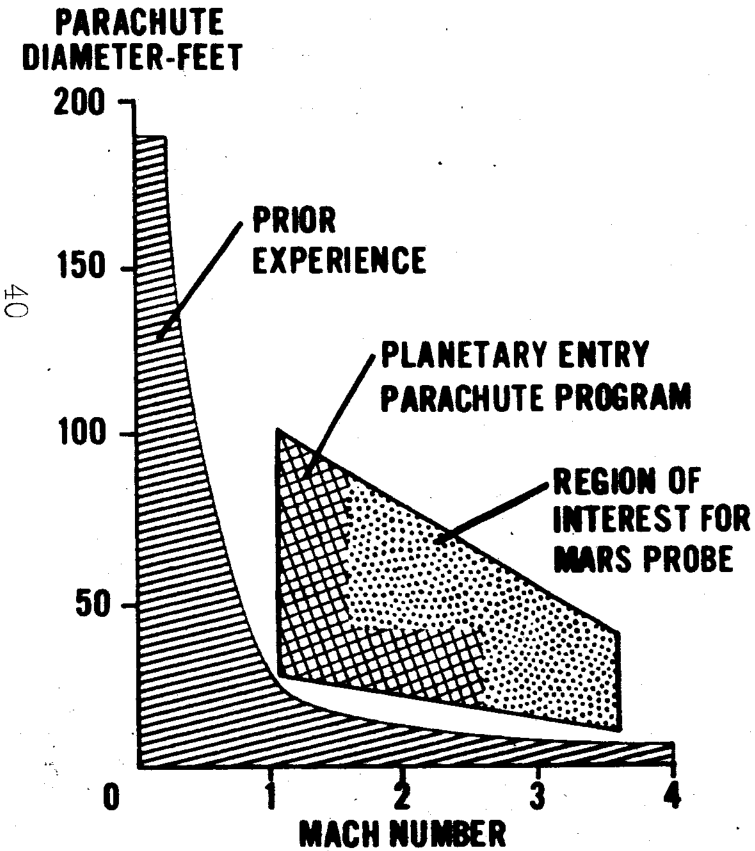
FY68-FY69
GOALS

- FABRICATE 250 FT^2 MODEL
- 2500 W OUTPUT
- 30 W/LB.

Figure 11

PLANETARY ENTRY PARACHUTE PROGRAM

SIMULATED MARS PARACHUTE DEPLOYMENT



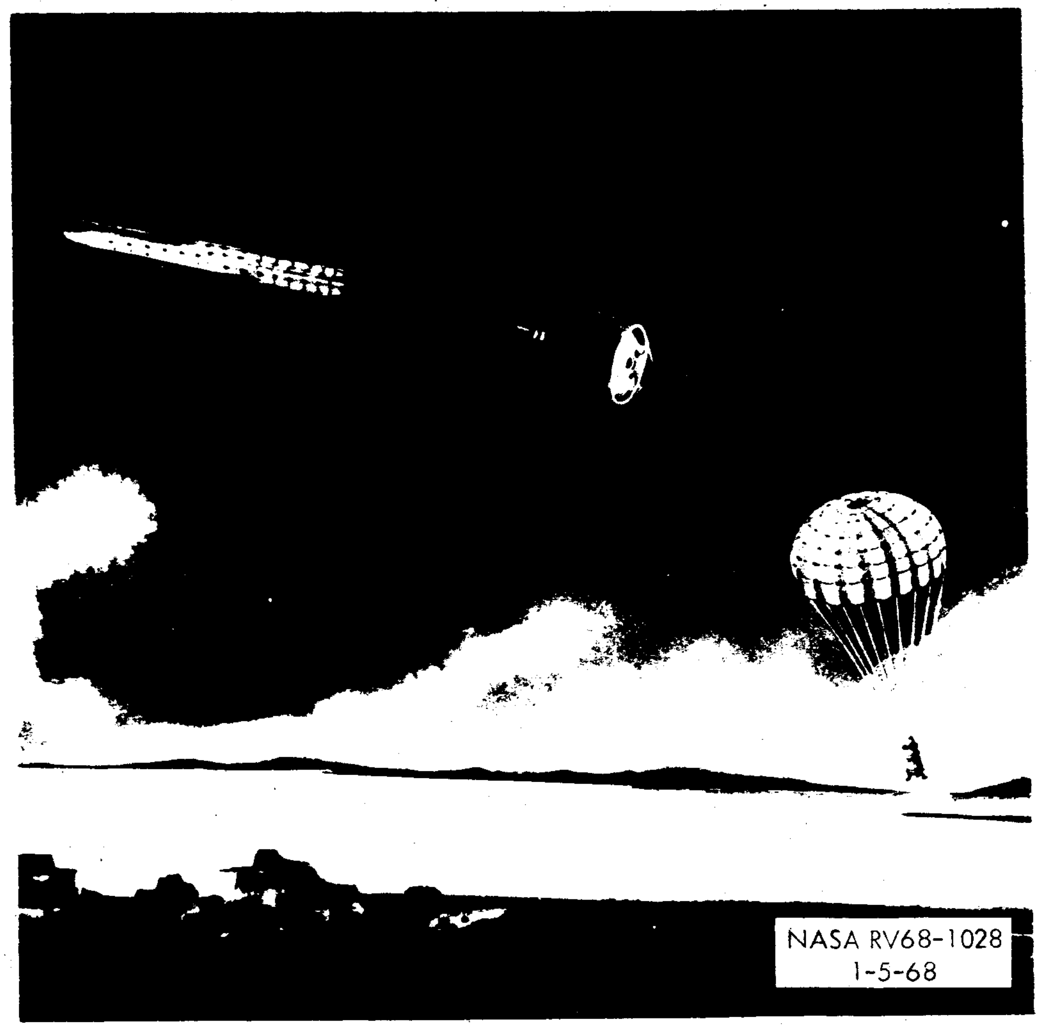


Figure 12

PARTS/DEVICES TREND

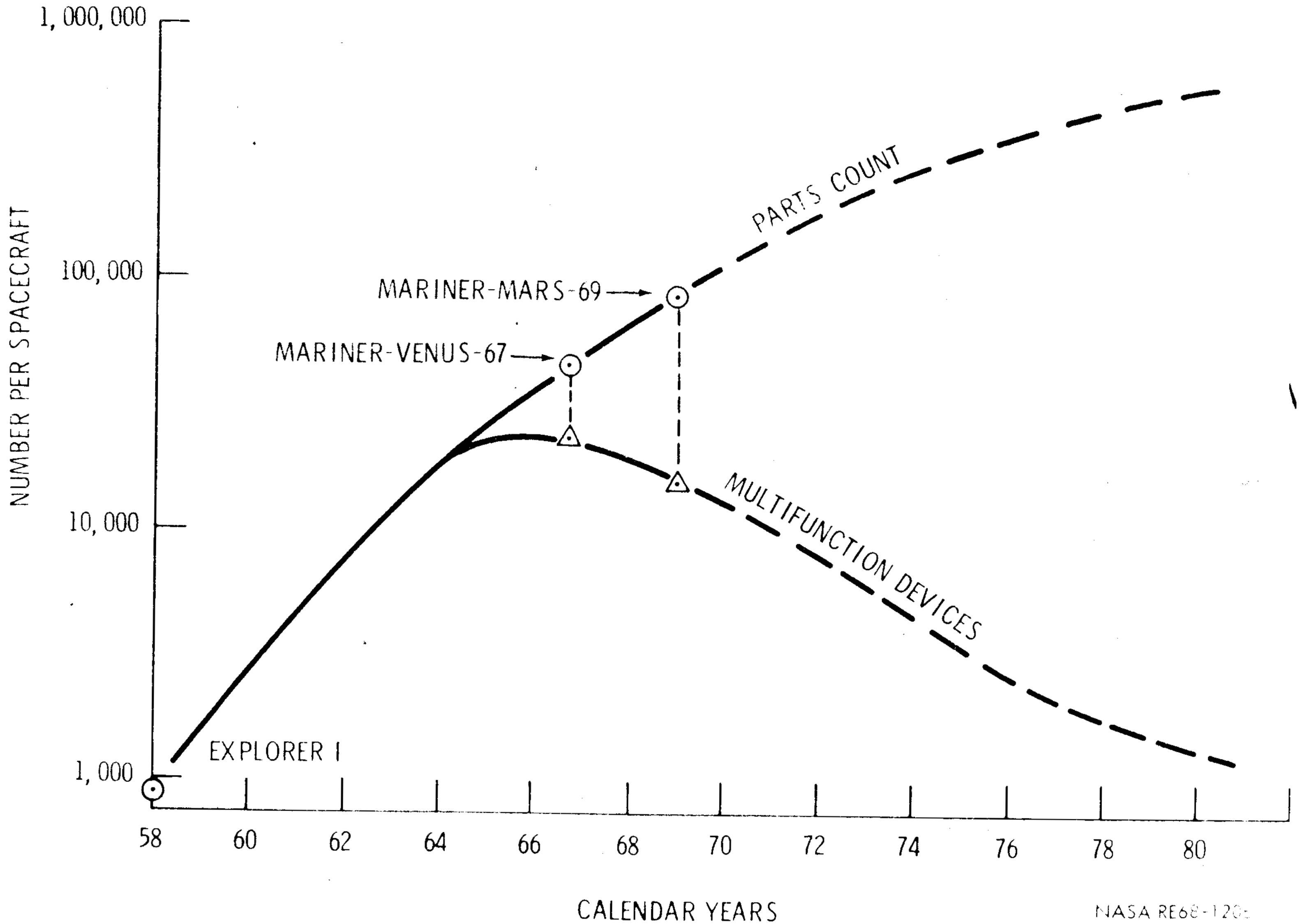
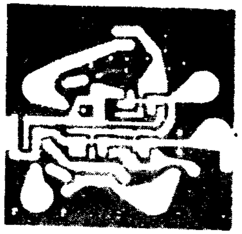


Figure 13

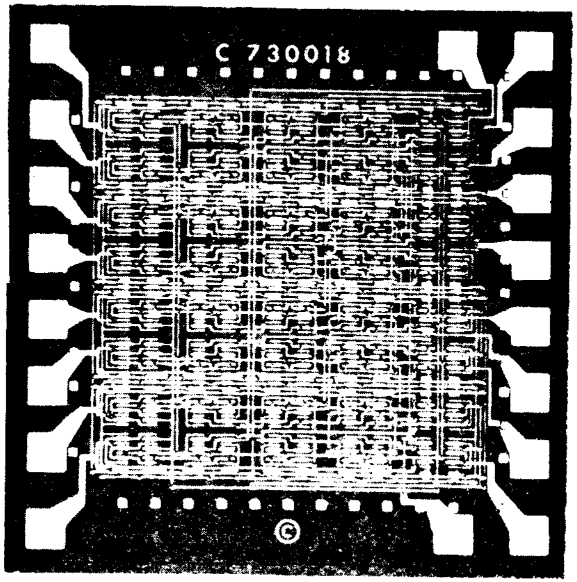
MULTICIRCUIT ARRAYS



40 X MAGNIFICATION

SINGLE-CIRCUIT SILICON DEVICE

PERFORMS 1 FUNCTION



40 X MAGNIFICATION

MULTI-CIRCUIT (LSI) DEVICE

PERFORMS 100 FUNCTIONS

- WITH 1/3 THE NUMBER OF PROCESS STEPS
- WITH 1/100 THE NUMBER OF HAND CONNECTIONS
- IN 1/10 THE WEIGHT AND VOLUME

NASA RE 67-1302
REV. 12-15-67

Figure 14